Prospects on constraining ΔG from A_{LL} for inclusive jet production at RHIC in 2003

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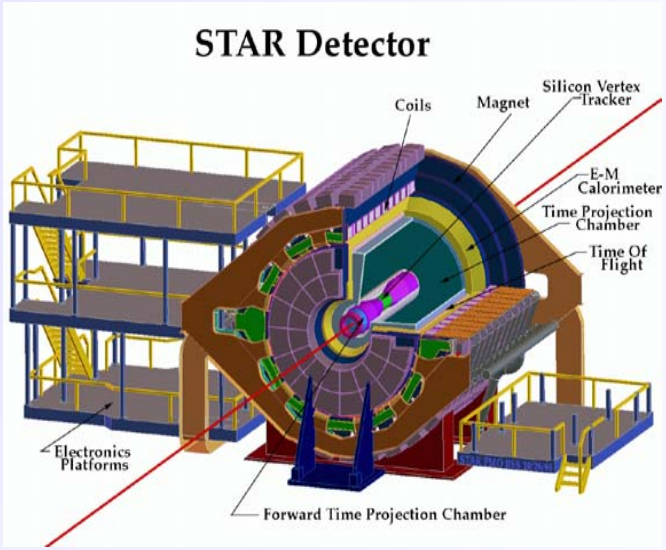
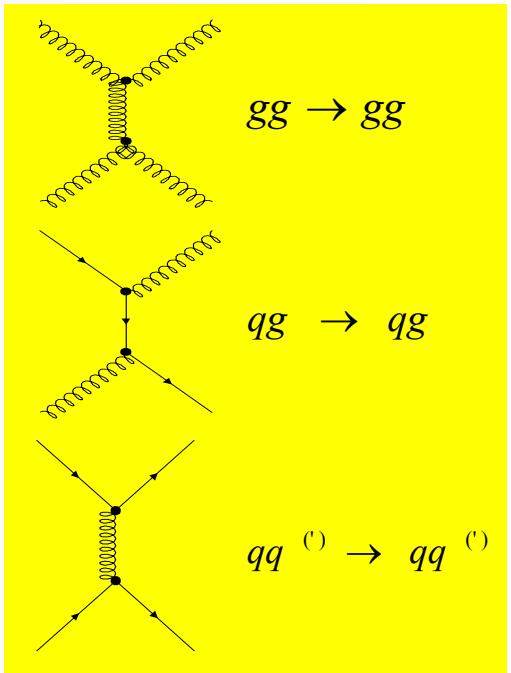
BNL

On behalf of the
STAR Collaboration

Outline





- STAR experiment (EMC/EEMC)
- Polarized proton collider RHIC (FY02-> FY03)
- Introduction (ΔG)
- Inclusive jet production
- Summary and Outlook

Introduction (ΔG)

- Background and status on ΔG

- Fundamental question: How is the proton spin made up?

$$J = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_z^q + L_z^g$$

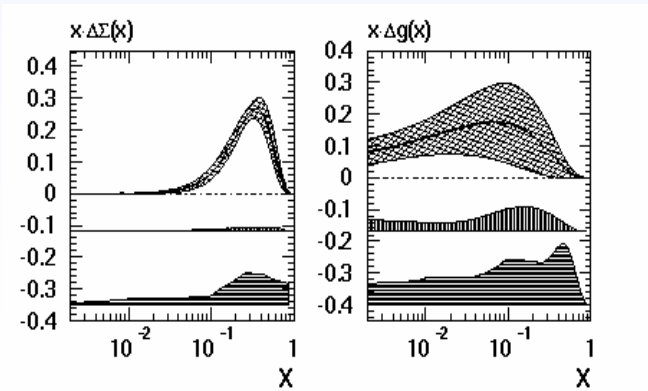
⇨ SMC result: Fraction of proton spin carried by quarks is small:

$$\Delta\Sigma_{(AB)} = 0.38\ ^{+0.03+0.03+0.03}_{-0.03-0.02-0.05} \text{ at } Q^2 = 1\text{GeV}^2$$

⇨ Where is the spin of the proton then?

$$\Delta G \text{ and } (L_z^q + L_z^g)$$

⇨ SMC QCD-fit:



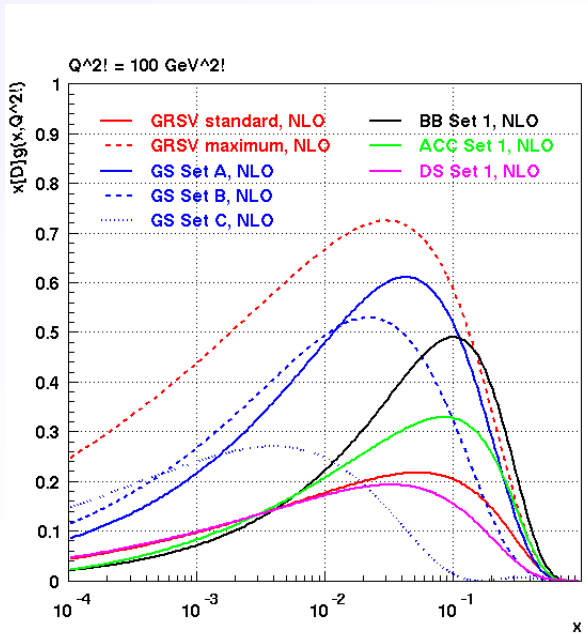
- At present: ΔG is only poorly constrained from scaling violations in fixed target DIS experiments

$$\Delta G_{(AB)} = 0.99\ ^{+1.17+0.42+1.43}_{-0.31-0.22-0.45} \text{ at } Q^2 = 1\text{GeV}^2$$

SMC, Phys. Rev. D58 (1998) 112002.

- Need: New generation of experiments to explore the spin structure of the proton: polarized proton collisions at RHIC which allows to access directly ΔG in polarized pp collisions!

- ΔG results of Global QCD-fits:

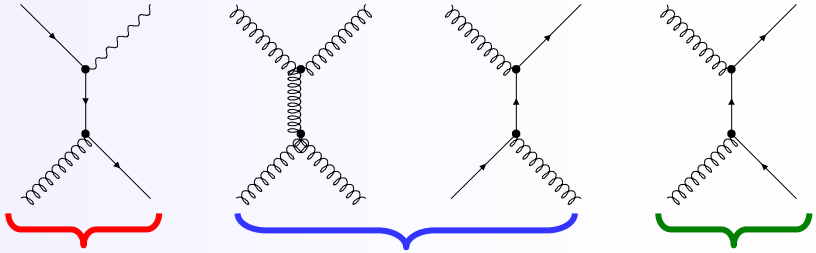


Introduction (ΔG)

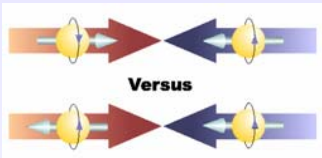
STAR spin

Access ΔG in polarized pp collisions

- ΔG sensitivity in polarized pp collisions
  - ⇨ High-p_T (prompt) photon production
  - ⇨ Jet production
  - ⇨ Heavy-flavor production



- Access ΔG: Double longitudinal-spin asymmetry A_{LL}



$$A_{LL} = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$

⇨ Study helicity dependent structure functions!

- Measurement of A_{LL} requires:

$$A_{LL} = \frac{1}{P_1 P_2} \cdot \frac{N_+ - R N_-}{N_+ + R N_-}$$

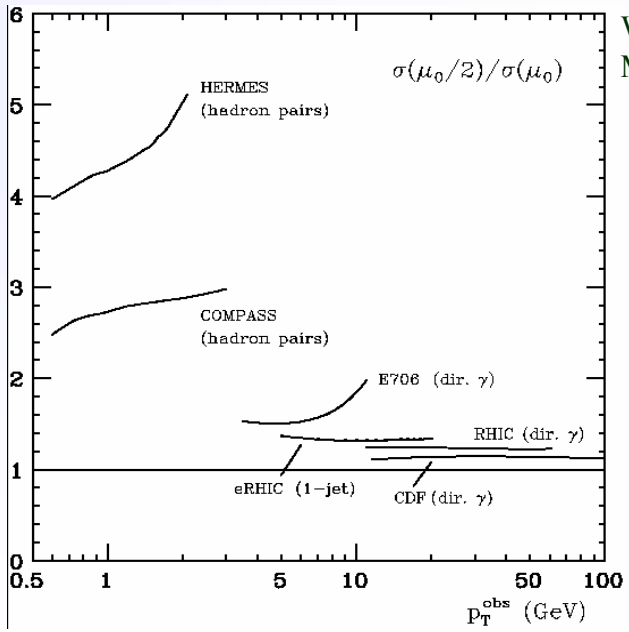
$$\delta A_{LL} = \frac{1}{P_1 P_2} \cdot \sqrt{\frac{1-(P_1 P_2 A_{LL})^2}{N_+ + R N_-}}$$

1. $N_{+(-)}$: Spin dependent event yield
2. R: Relative luminosity
3. P: Beam polarization

- FOM (= Figure-Of-Merit):

⇨ A_N/A_L: $P^2 \cdot \int Ldt$ ⇨ A_{LL}/A_{TT}: $P^4 \cdot \int Ldt$

- Theoretical advantage of RHIC:



W. Vogelsang, M. Strattmann

⇨ Smaller scale dependence at RHIC compared to HERMES/COMPASS!

Introduction (ΔG)

STAR spin

- The golden channel at RHIC: Quark-Gluon Compton scattering (1)
  - A_{LL} for QGC scattering interpreted in LO QCD: $gq \to \gamma g$

$$A_{LL} \cong \frac{\Delta G(x_g)}{G(x_g)} \cdot A_1^p(x_q) \cdot \hat{a}_{LL}^{(g+q\to\gamma+q)}(\cos\vartheta^*)$$

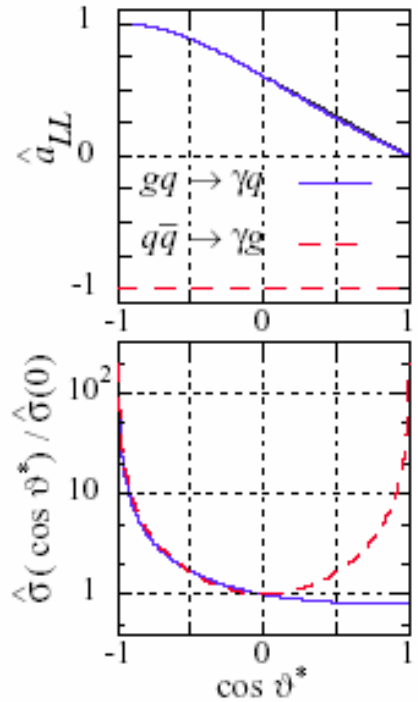
Gluon polarization

Measured asymmetry from polarized DIS

pQCD result for QGC scattering

⇨ Polarized cross-section is strongly peaked when photon is emitted in direction of incident quark

⇨ Best determination of ΔG for: final-state photon || to initial-state quark



⇨ Note: QGC scattering dominates over competing background process: $q\bar{q} \to \gamma g$

  - Reconstruction of initial-state partonic kinematics:

⇨ Event-by-event determination of $p_{T,\gamma}$ (photon energy), η_γ (photon direction) and η_{jet} (jet direction) allows to reconstruct:

$$x_{1(2)} \cong \frac{p_{T,\gamma}}{\sqrt{s}}\left(e^{\pm\eta_\gamma} + e^{\pm\eta_{\text{jet}}}\right)$$

$$x_q^{recon} = \max[x_1, x_2]$$
$$x_g^{recon} = \min[x_1, x_2]$$

⇨ Large x quark (large quark polarization) analyzes small-x gluons (gluon-rich)

⇨ Asymmetric QGC scattering (forward boost in direction of incident quark)

- Background:

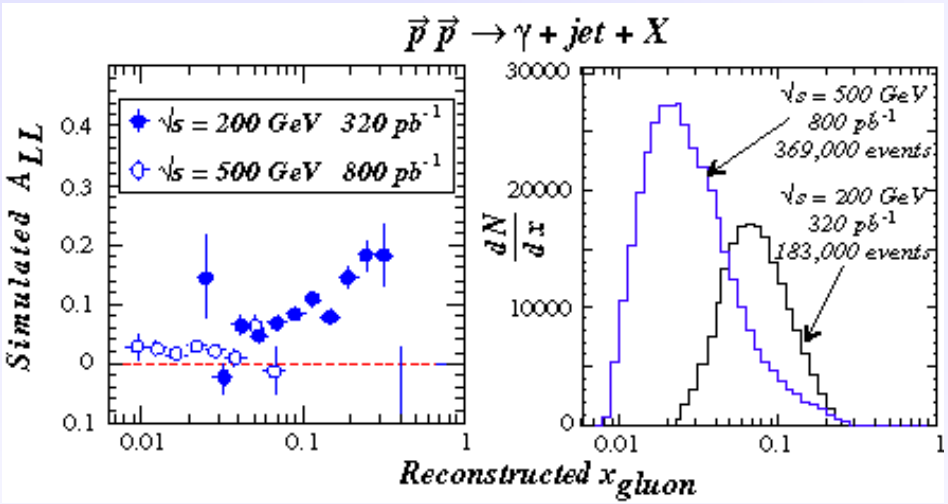
⇨ $\pi^0(\eta^0) \to \gamma\gamma$: $\pi^0(\eta^0)/\gamma$ discrimination needed

⇨ Isolation cone requirement

Introduction (ΔG)

STAR spin

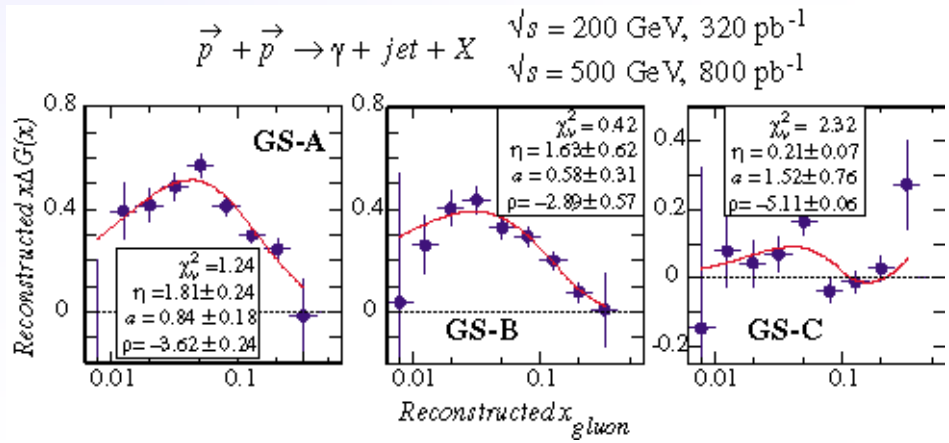
- The golden channel at RHIC: Quark-Gluon Compton scattering (2)
  - Simulated A_{LL} at two different RHIC center-of-mass energies:



⇨ Multi year program at RHIC which requires:

1. High luminosity
2. High polarization
3. √s = 200 / 500GeV

$$A_{LL} \cong \frac{\Delta G(x_g)}{G(x_g)} \cdot A_1^p(x_q) \cdot \hat{a}_{LL}^{(g+q\rightarrow\gamma+q)}(\cos\vartheta^*)$$



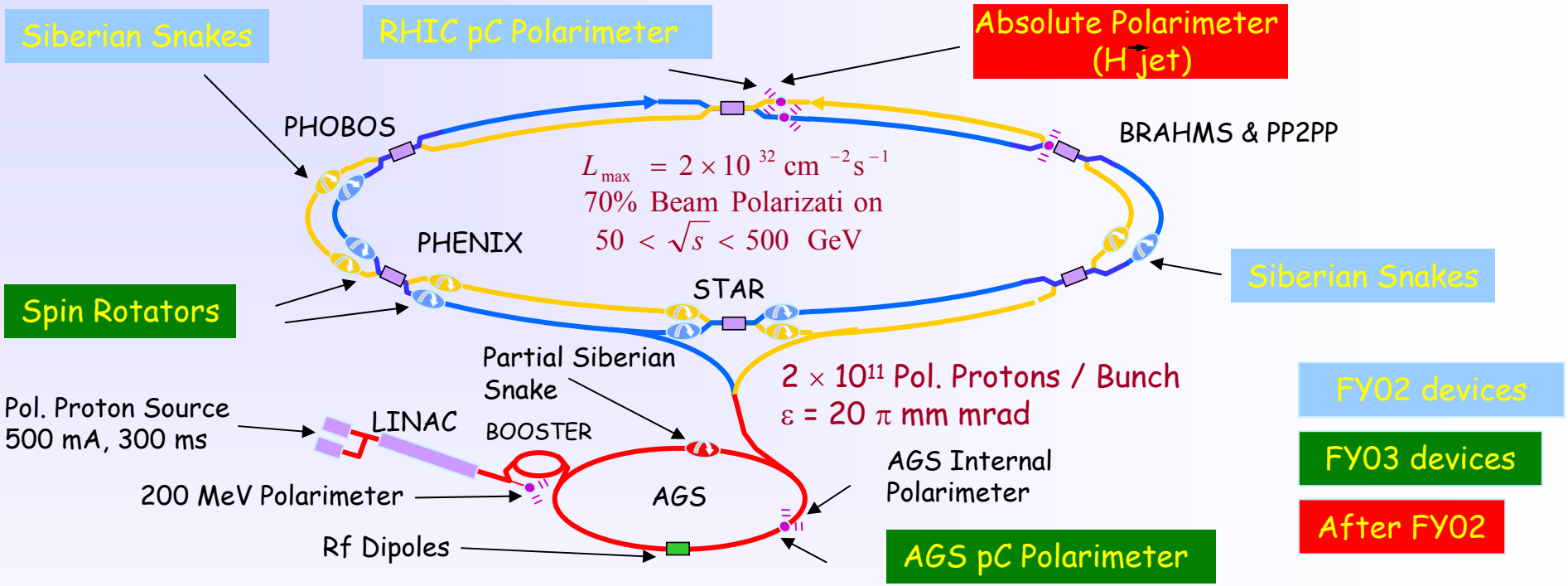
⇨ Combined data sample at 200 GeV and 500 GeV is essential to minimize extrapolation errors in determining ΔG:

$$\Delta G(Q^2) = \int_0^1 \Delta g(x, Q^2)\,dx$$

Accuracy: 0.5

⇨ Ultimately: Global analysis of various ΔG!

Polarized pp collider RHIC



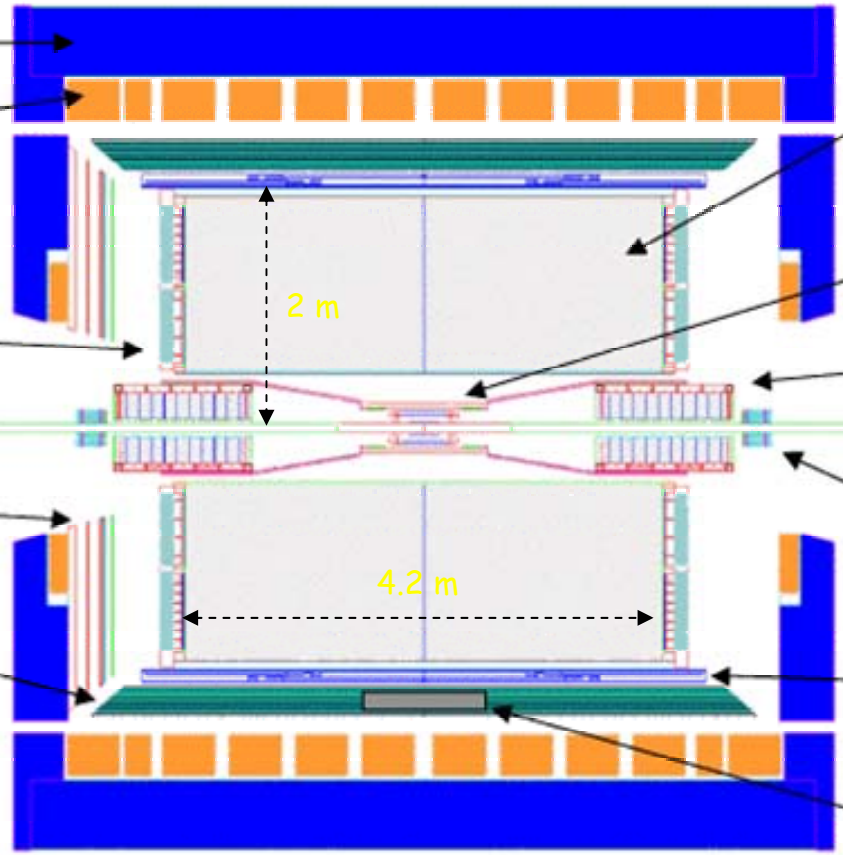
- RHIC performance in FY02:
  - ⇨ Beam energy: 100 GeV
  - ⇨ Inst. luminosity: ~ $1 \cdot 10^{30}\ s^{-1}\ cm^{-2}$
  - ⇨ Integrated luminosity: ~ $0.3 pb^{-1}$
  - ⇨ Bunch crossing time: 213ns
  - ⇨ Polarization: ~ 0.2 at injection approximately maintained at 100GeV (transverse)

- Expected RHIC performance in FY03:
  - ⇨ Beam energy: 100 GeV
  - ⇨ Inst. luminosity: ~ $1 \cdot 10^{31}\ s^{-1}\ cm^{-2}$
  - ⇨ Integrated luminosity: ~ $3\ pb^{-1}$ recorded at STAR (long. polarization)
  - ⇨ Bunch crossing time: 107ns
  - ⇨ Polarization: ~ 0.4 from AGS (trans. and long. at RHIC)

STAR experiment (EMC/EEMC)

STAR spin

Spin | Before FY02 | FY02 | FY03 and beyond



Magnet Coils

B=0.25T 0.5T

TPC Endcap & MWPC

ZCal

Endcap EMC
1< η <2 Δφ = 2π

Barrel EMC
0< η< 1 Δφ =2π/5
|η| < 1 Δφ = 2π

Time Projection Chamber |η|< 1.5

Silicon Vertex Tracker

Forward TPCs
2.4 <|η| < 4.0

Vertex Position Detectors

Central Trigger Barrel |η|<1 TOF patch

RICH: |η|<0.3, ΔΦ = π/6

$$\eta = -\ln\left[\tan\left(\theta/2\right)\right]$$

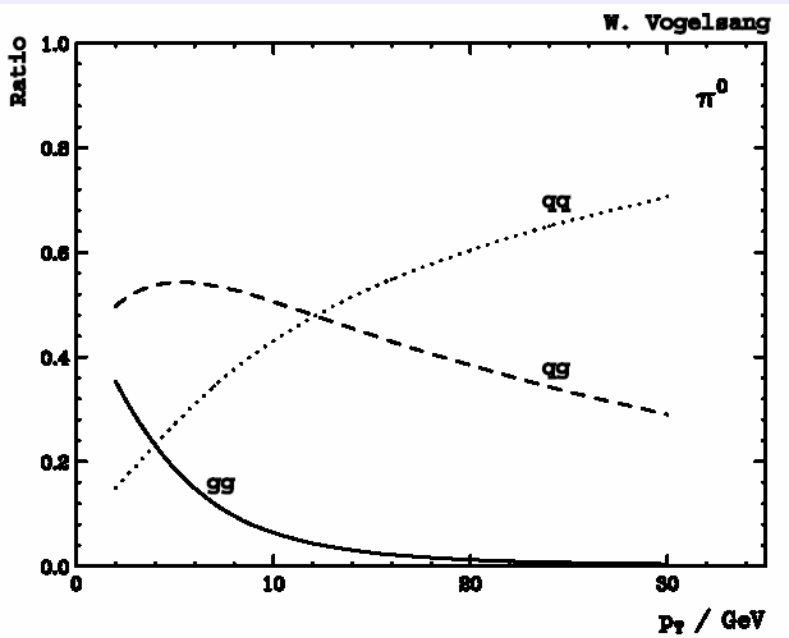
Forward Pion Detector 3.1 < η < 4.4

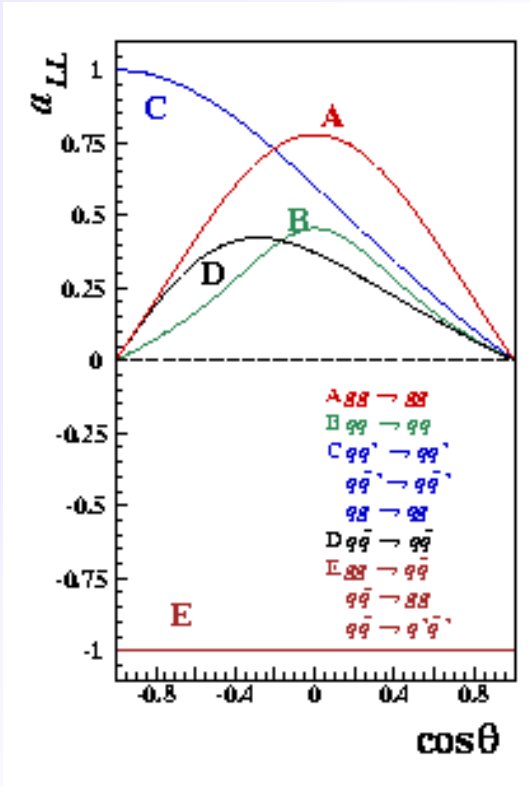
Beam-Beam Counters
2 < |η| < 5

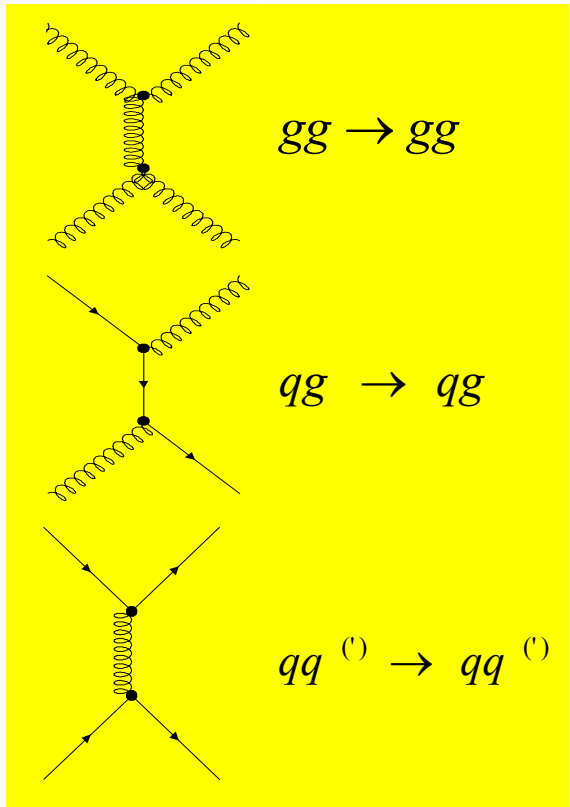
Inclusive jet production

- General remarks

- Mixture of gg / qg /qq$^{(')}$ scattering
- Sensitive to ΔG
- High statistics





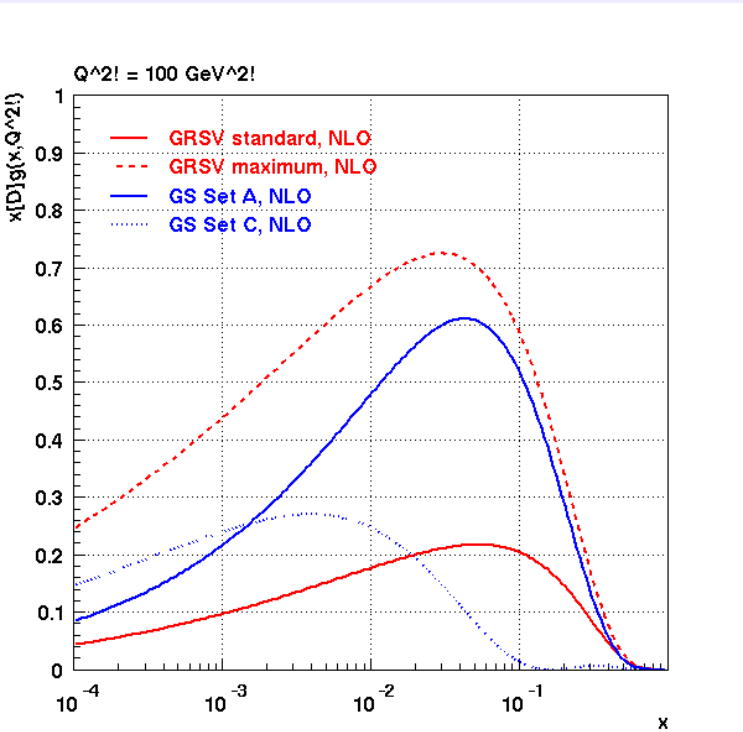


Inclusive jet production

- NLO calculation (A_{LL} sensitivity for GRSV)

W. Vogelsang

- Luminosity: $3pb^{-1}$
- $\sqrt{s}$=200GeV
- Polarization: 0.4
- Assume: Coverage of EMC (barrel)
  ⇨ $0 < \Phi < 2\pi$ and $0 < \eta < 1$



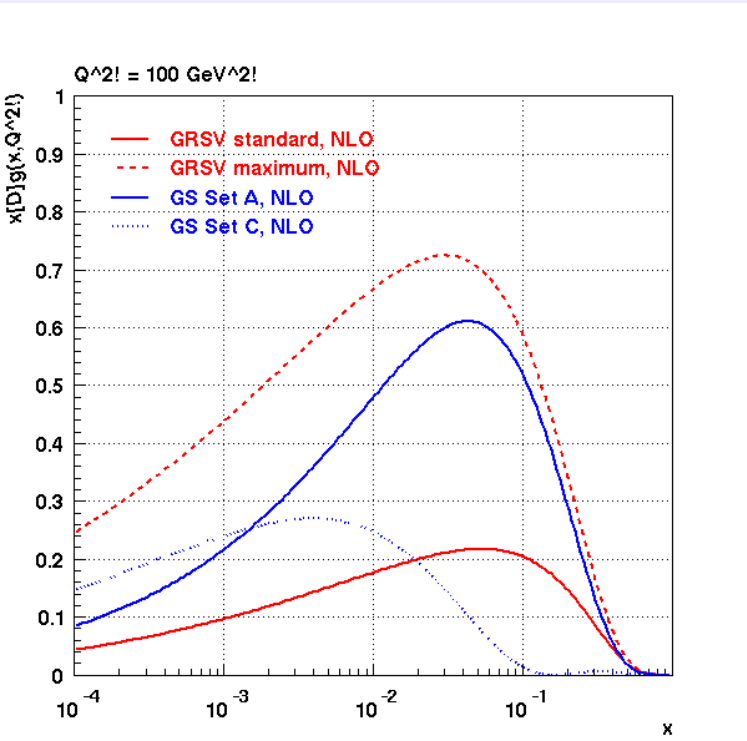
⇨ Clear sensitivity in A_{LL} between ΔG of GRSV-max and GRSV-std!

Inclusive jet production

- NLO calculation (A_{LL} sensitivity for GS)

W. Vogelsang

- Luminosity: $3pb^{-1}$
- $\sqrt{s}$=200GeV
- Polarization: 0.4
- Assume: Coverage of EMC (barrel)
  ⇨ $0 < \Phi < 2\pi$ and $0 < \eta < 1$



⇨ Clear sensitivity in A_{LL} between ΔG of GS-A and GS-C!

Inclusive jet production

STAR spin

Rates

- Anticipated performance of RHIC in FY03:

⇨ Beam energy: 100 GeV

⇨ Inst. luminosity: ~ $1 \cdot 10^{31}$ s^{-1} cm^{-2}

⇨ Integrated luminosity: ~ 3 pb^{-1} (long. Polarization)

⇨ Bunch crossing time: 107ns

⇨ Polarization: ~ 0.4 from AGS (transverse and longitudinal at RHIC)

- Anticipated Jet-Trigger:

⇨ Trigger requirement: ΣE_T > 6 GeV over EMC/EEMC jet patches

⇨ Rate: 40 Hz

⇨ Yield for 10 days at 33% efficiency (~3pb^{-1}):

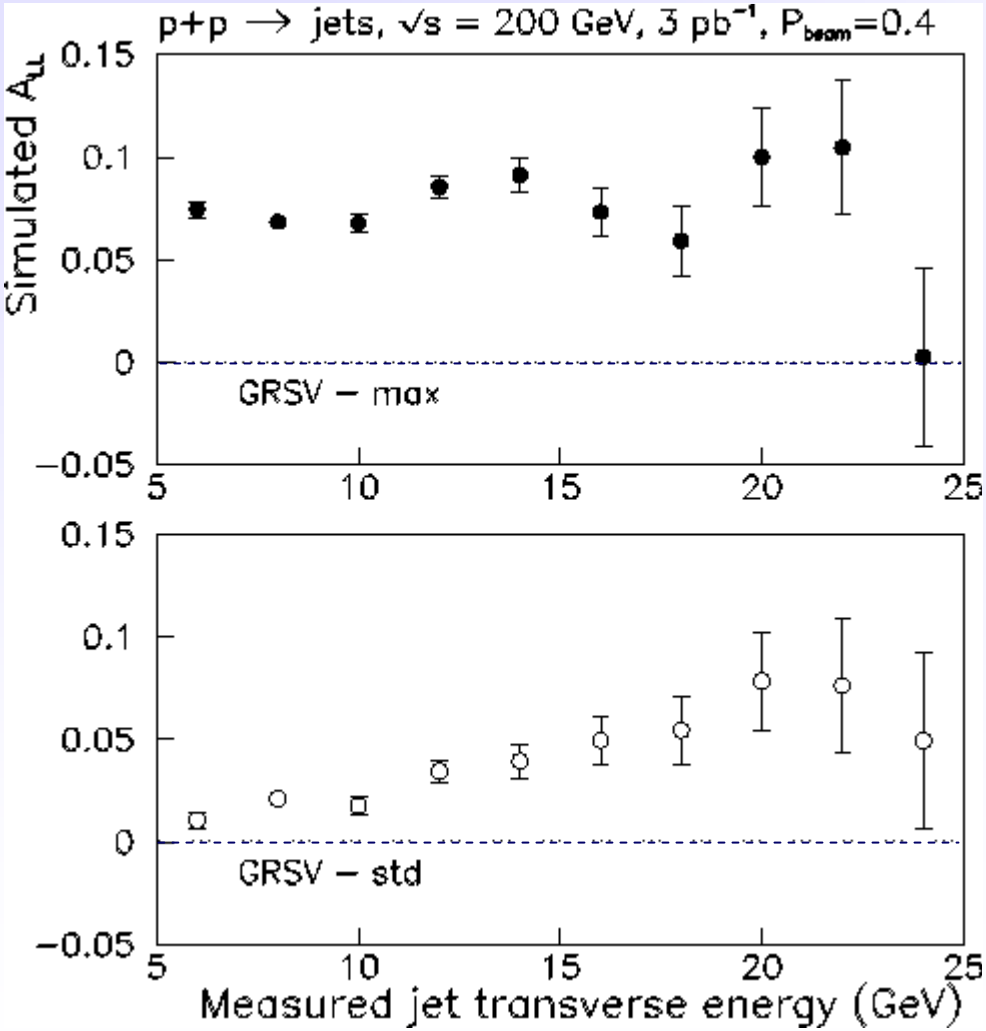
⇨ ~ 1 X 10^6 jets for p_T = 5 – 10 GeV

⇨ ~ 9 X 10^4 jets for p_T = 15 – 20 GeV

⇨ ~ 1 X 10^3 jets for p_T = 30 – 35 GeV

Inclusive jet production

- A_{LL} sensitivity (incl. detector effects)



- Simulation based on Pythia including trigger and and jet reconstruction efficiencies
- Assume: Coverage of EMC (barrel)
  ⇨ $0 < \Phi < 2\pi$ and $0 < \eta < 1$
- Jet Trigger: $E_T > 5$ GeV over at least one "patch" ($\Delta\eta = 1$) X ($\Delta\Phi = 1$)
- Jet reconstruction: Cone algorithm (seed = 1GeV, R = 0.7)
- Luminosity: $3pb^{-1}$
- Polarization: 0.4
- $\sqrt{s}$ = 200GeV

Inclusive jet production

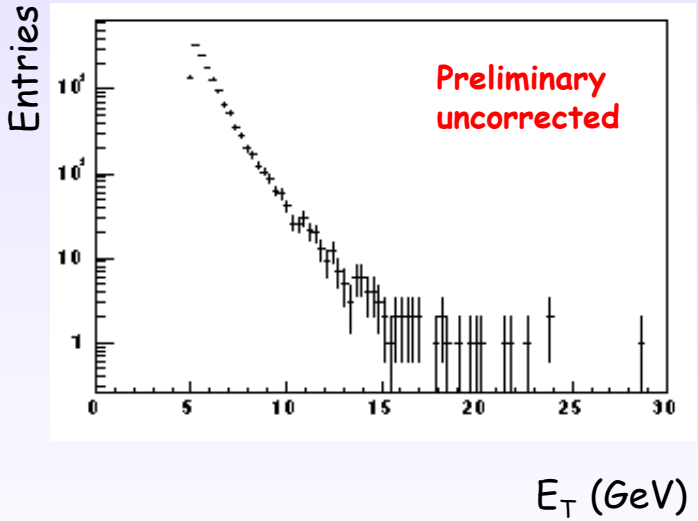
STAR spin

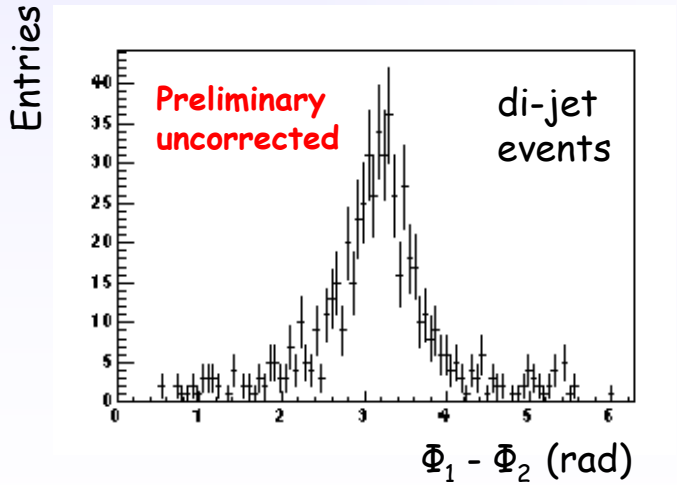
Systematic errors

- Polarization:
  - ⇨ Absolute polarization uncertainty at injection: ~ ± 20%
  - ⇨ Need RHIC down-ramping development to determine uncertainty at $\sqrt{s}$ = 200 GeV
  - ⇨ Ultimately: RHIC Polarized jet target to aim for an absolute polarization uncertainty of ~ ± 5%
- Relative luminosity (R) measurement:
  - ⇨ Study of background contribution to R measurement (Talk by J. Kiryluk)
  - ⇨ Study of possible spin dependence in monitoring process for R measurement
- Trigger bias:
  - ⇨ Difference in fragmentation function of quark over gluon jets!
  - ⇨ Employ different jet triggers to study those uncertainties!
- Tuning of spin rotators: (Talk by A. Ogawa)

Status of FY02 jet analysis

- Very first "look" at jets:
  - ⇨ DATA: STAR minimum-bias pp data: $\sqrt{s}$ = 200 GeV
  - ⇨ Jet algorithm: Cone jet Finder for charged particles only: R = 0.7, seed > 1GeV, E_T > 5GeV, $|\eta^{jet}| < 0.7$
  - ⇨ Quantitative comparison to MC simulations (e.g. Pythia) requires detailed studies of detector efficiencies





- First "look" to "see" jets is encouraging in view of our spin program ("inclusive jets") in FY03!
- NOTE: Realistic simulations to account for detector efficiencies are required!

Summary and outlook

Summary

⇨ First collisions of longitudinally polarized protons expected for FY03

⇨ Sensitivity to ΔG from A_{LL} measurement for FY03 in inclusive jet production

- NLO calculations
- Simulations
- Systematic errors

⇨ First "look" towards jets in FY02 data looks encouraging

Outlook

⇨ Various upgrade programs are underway at STAR which are crucial to measure A_{LL}:

- Electromagnetic barrel/endcap calorimeter
- Beam-Beam counter ⇨ J. Kiryluk (Relative luminosity measurement) / Forward-Pion Detector ⇨ G. Rakness and ⇨ A. Ogawa (Tune of spin rotators) Mid-rapidity: J. Balewski

⇨ A very exciting time is ahead of us to explore the spin structure of the proton at RHIC!